Hoitsema has shown that Troost and Hautefeuille's deduction that a compound exists having the formula Pd_2H is not warranted. The constancy of the heat of occlusion over the whole range of absorption is also opposed to the view that such a compound is formed.

The composition of fully charged palladium hydrogen corresponds closely with the formula Pd_3H_2 first suggested by Dewar. The principal and almost only evidence, up to the present, in favour of the formation of such a definite chemical compound is to be found in the approximation of the above atomic ratios to the theoretical value 1·5, required by the formula Pd_3H_2. Although Hoitsema's arguments may be equally well directed against the existence of this compound, the authors consider that additional and independent evidence is desirable, and hope to be able to provide it.

It is also shown that the heats of occlusion of hydrogen in platinum and palladium black are not in favour of the view which has sometimes been put forward that the heat of occlusion of a gas represents the heat of condensation or liquefaction of the gas in the capillary pores of the absorbing substance, or the heat of solidification or fusion.

"On the Determination of the Indices of Refraction of various Substances for the Electric Ray. II. Index of Refraction of Glass." By JAGADIS CHUNDER BOSE, M.A., D.Sc., Professor of Physical Science, Presidency College, Calcutta. Communicated by LORD RAYLEIGH, F.R.S. Received October 1,—Read November 25, 1897.

In my previous paper, read before the Royal Society on October 20, 1895,* I described a method of determining the indices of refraction of various substances for electric radiation, the principle of which depends on the determination of the critical angle at which total reflection takes place. A semi-cylinder of the given substance was taken, and the angle of incidence gradually increased till the rays were totally reflected. The experiment was repeated with two semi-cylinders, separated by a parallel air-space. The advantage of the latter arrangement was that the image cast by the two semi-cylinders remained fixed. The image underwent extinction when the angle of incidence attained the critical value.

The determination of the indices of refraction for long electric waves derives additional interest from Maxwell's theoretical relation between the dielectric constant and the refractive index for infinitely long waves. The relation $K=\mu^2$ has, however, been found to be fulfilled in only a few instances. The value u_∞ is usually deduced

* *Vide* 'Roy. Soc. Proc.,' vol. 59, p. 160.

from Cauchy's formula, which is admittedly faulty when applied to rays below the visible spectrum. It would therefore be of interest to be able to measure *directly* the index for long electric waves, and compare it with the value of K for rapidly alternating electric fields, the periodicity of which is preferably of the same order as that of the electric waves for which the index is determined.

Among the substances in which great divergence is exhibited between the values of K and μ^2, glass may be taken as typical. In the very carefully conducted series of experiments by Hopkinson the value of K (later results) was found to be 6·61 for light flint and 9·81 for extra dense flint glass. He found no variation of K with the time of charge, which varied from 1/4 to 1/20,000 part of a second.* Messrs. Romich and Nowak† found the value to be 7·5 for alternation of field of about once in a second, while for steady fields they obtained the abnormally high value of 159. Schiller‡ found K for plate glass to be 6·34, with a frequency of alternation of 25 in a second. With a higher frequency of about $1{\cdot}2 \times 10^4$, the value obtained was lower, *i.e.*, 5·78. Gordon, with a frequency of $1{\cdot}2 \times 10^4$, obtained 3·24 as K for common glass.

From the experiments of Schiller it would appear that the value of K for glass diminished with the increase of frequency of alternation of the field.

Rubens and Arons§ compared the velocities of propagation of electro-magnetic action through air and glass, and obtained the ratio of the velocities or $\mu = 2{\cdot}33$. The deduced value of K would therefore be 5·43. M. Blondlot‖ found K to be 2·84 when the frequency of vibration was of the order $2{\cdot}5 \times 10^7$. Professor J. J. Thomson found the specific inductive capacity of glass to be smaller under rapidly changing fields than in steady ones. He deduced the value of K by measuring the lengths of wave emitted by a parallel plate condenser with air and glass as dielectrics. The value for glass was found to be 2·7.¶

On the other hand, Lecher** found that the dielectric constant rose with the frequency of vibration. Thus for plate glass—

Frequency.	K.
2	4·64
2×10^3	5·09
$3{\cdot}3 \times 10^6$	6·50

* Hopkinson, 'Phil. Trans.,' 1881, Part II.

† 'Wien. Ber.,' vol. 70, 1874.

‡ 'Pogg. Ann.,' p. 152, 1874.

§ 'Wied. Ann.,' vol. 42, p. 581; vol. 44, p. 206.

‖ 'Compt. Rend,' May 11, 1891, p. 1058.

¶ 'Roy. Soc. Proc.,' vol. 46, p. 292.

** 'Phil. Mag.,' vol. 31, p. 205.

There is thus a serious difference between the two views of the variation of K (and therefore of μ) with the frequency of vibration. In a previous paper,* I alluded to the probability of the variation of μ with the frequency of vibration. The value of μ may at first undergo a diminution with the increase of frequency, reach a minimum, and then have the value augmented when the frequency rises above the critical rate. The result obtained by Lecher is, however, too divergent from the others to be explained by such a supposition.

The direct determination of μ for glass for electric oscillations of high frequency, seemed to me of interest, as throwing some light on the controversy; so, on the conclusion of my determination of the index for sulphur, I commenced an investigation for the determination of μ for glass. This was, however, greatly delayed by repeated failures to cast glass here, and by my long absence from India. I have now obtained from England two semi-cylinders of glass, with a radius = 12·5 cm. and height = 8 cm.

The method of experiment followed is the same as that described in my previous paper. The radiator is placed at the principal focus (obtained from a preliminary experiment) of one of the semi-cylinders. The cylinder mounted on the platform of a spectrometer is rotated till the rays are totally reflected. From the critical angle the value of μ is deduced.

I shall here describe some modifications introduced in the apparatus, which have been found to be great improvements. One of the principal difficulties met with was in connexion with the disturbance caused by stray radiation. It is to be remembered that the receiver is extremely sensitive. Comparatively long waves are found to possess very great penetrative power; shielding the receiver then becomes very difficult. Even after the receiver, the galvanometer, and the leading wires had been screened, disturbances were met with which it was difficult to localise. Part of the disturbance may have been due to that set up by the generating coil. A double box made of soft iron and thick copper removed this difficulty. But the greatest immunity from disturbance was secured by using short waves. In this case it was not at all necessary to take very special precautions to shield either the galvanometer or the leading wires, the sensitive layer in the receiver alone being affected by the radiation. I exposed the bare leading wires to the strong action of the radiator by putting them in close proximity to the source of radiation, and yet no response was observed in the galvanometer. This freedom from disturbance is not due to the opposite action on the two wires, for a single wire may be exposed to the radiation without any action on the receiver.

* *Vide* 'Roy. Soc. Proc.,' vol. 60, p. 168.

With small radiators the intensity of radiation is not very great. This is a positive advantage in many experiments. It sometimes becomes necessary to have greater intensity without the attendant trouble inseparable from too long waves. I have made a new radiator, where the oscillatory discharge takes place between two small circular plates 12 mm. in diameter and an interposed ball of platinum 9·7 mm. in diameter. The sparking takes place at right angles to the circular plates. The intensity of radiation is by this expedient very greatly increased.

In my previous experiments to determine the index of refraction, I used tubes to surround the radiator. This I was obliged to do to protect the receiver as much as possible from external disturbances. But this procedure may be open to the objection that the sides of the tube may send reflected waves. It is preferable to have a divergent beam from a single source form a well-defined image after refraction. Owing to the successful removal of the disturbing causes it is now possible to allow the radiator to be placed in open space, a plate with a rectangular aperture allowing the radiation to fall on the refracting cylinder along a given direction. The size of the plate is 26×15 cm., and the aperture is 7×6 cm. (see fig. 1). The radiator and the receiver are placed on opposite sides of the plate. Absence of disturbance due to lateral waves was tested by closing the aperture and observing whether the waves still affected the receiver by going round the plate. The plate was found to act as an effective screen.

I have hitherto preferred the null method in my experiments, as it possesses many advantages. The sensitiveness of the receiver can be pushed to the utmost extent, and observations taken when no effect is produced on the receiver. The total reflection method also dispenses with the difficulty of making accurate measurement of the deviation produced. After obtaining the value of the index by the method described above, I was desirous to see whether it was not possible to obtain fairly good results by measuring the angle of refraction corresponding to a given angle of incidence. I shall presently describe the difficulties met with in these experiments, and the manner in which they were to a great extent removed.

The preliminary experiment was carried out with a single semi-cylinder. The angle of incidence was gradually increased by rotating the cylinder, and the refracted beam was followed with the receiver. In this way it was found that the rays ceased to be refracted when the angle of incidence was about 28° 30′. The critical angle is therefore 28° 30′ and

$$\mu = 2{\cdot}08 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1).$$

I next used two semi-cylinders. The plane vertical face of the

semi-cylinder near the radiator, was placed along a diameter of the spectrometer circle. The second semi-cylinder was separated from the first by an air-space 2 cm. in breadth. The plane surfaces of the two semi-cylinders were thus separated by a parallel air-space; the first semi-cylinder rendered the beam parallel, and the second focussed the rays on the receiver placed opposite the radiator. With the radiator used, I found a thickness of 2 cm. of air-space to be more than sufficient for total reflection of the incident ray.*

On rotating the cylinders to the right and to the left, two positions for total reflection were obtained. The difference of circle readings for these positions, equal to twice the critical angle, was found to be 58°. The critical angle for glass is therefore 29°.

$$\mu = 2{\cdot}04 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2).$$

Having thus obtained the value of the index, I tried to find whether it would be possible to obtain approximately good results by measuring the deviation of the refracted ray. In the first series of experiments, I used for this purpose a semi-cylinder, with the radiator at its principal focus (the cylindrical surface being next to the radiator), so that the emergent rays were parallel. On trying to find the angle of refraction corresponding to a given angle of incidence, I could obtain no definite reading, as the receiver continued to respond, when moved through five or six degrees on either side of the mean position where the response was strongest. It must be remembered that owing to the finite length of the waves, there is no well-defined geometrical limit to either the ray or the shadow. There is, however, a position for maximum effect, and it is possible with some difficulty so to adjust the sensitiveness of the receiver that it shall only respond to the maximum intensity.

Another troublesome source of uncertainty is due to the action of the tube which encloses the receiver. When a slanting ray strikes the inner edge of the tube, it is reflected and thrown on to the delicate receiver. Unfortunately it is difficult to find a substance which is as absorbent for electric radiation as lamp-black is for light. Lamp-black in the case of electric radiation produces copious reflection. I have tried layers of metallic filings, powdered graphite, and other substances, but they all fail to produce complete absorption. The only thing which proved tolerably efficient for this purpose was a piece of thick blotting paper or cloth soaked in an electrolyte. A cardboard tube with an inner layer of soaked blotting paper is impervious to electric radiation, and the internal reflection, though not completely removed, is materially reduced. No reliance can,

* *Vide* the following paper "On the Influence of the Thickness of Air-space on Total Reflection of Electric Radiation."

however, be placed on this expedient, when a very sensitive receiver is used.

After repeated trials with different forms of receiving tubes, I found a form, to be described below, to obviate many of the difficulties. Instead of a continuous receiving tube, I made two doubly inclined shields, and placed them one behind the other, on the radial arm which carries the receiver. The first shield has a tolerably large aperture, the aperture of the second being somewhat smaller. The size of the aperture is determined by the wave-length of radiation used for the experiment. It will be seen from this arrangement, that the rays which are in the direction of the radial arm, can effectively reach the receiver, the slanting rays being successively reflected by the two shields. With this expedient, a great improvement was effected in obtaining a definite reading.

When the deviated rays are convergent, the receiver is simply placed behind the shields, at the focus of the rays. But when the rays are parallel, the use of an objective (placed behind the first shield) gives very satisfactory results. As objectives I used ordinary glass lenses; knowing the index from my experiments, I was able to calculate the focal distance for the electric ray. This is of course very different from the focal distance for the luminous rays. I at first used a lens of 6 cm. electric focal distance, but this did not improve matters sufficiently. I then used one with a longer focus, *i.e.*, 13 cm., and this gave satisfactory results.

The receiver used to be enclosed in a metallic case, 2 cm. in breadth, with an open front for the reception of radiation. The case was used to protect the receiver from stray radiations. But by the new arrangement and improved construction, these disturbances were effectively removed. I therefore discarded the use of the metallic enclosing cell, as it seemed to me that the rays which did not actually fall on the sensitive surface might be reflected from the back of the metallic cell and thrown on to the sensitive layer. The layer of spirals, only 1·5 mm. in breadth, is laid on a groove in ebonite (which is transparent). This linear receiver without any metallic case was placed at the focus of the lens.

I now proceeded to measure the angle of refraction corresponding to a given angle of incidence. In the first series observed, the refraction was from glass to air; the cylindrical surface of the semi-cylinder was turned to the radiator, which was placed at its principal focus. The receiver was mounted on the radial arm with the double shields, and the objective in the manner already described. The reading for refracted rays was taken in the following manner. Having adjusted the semi-cylinder for a given angle of incidence, the receiver was moved round till it responded to the refracted ray. Readings were taken first by placing the receiver at an angle less

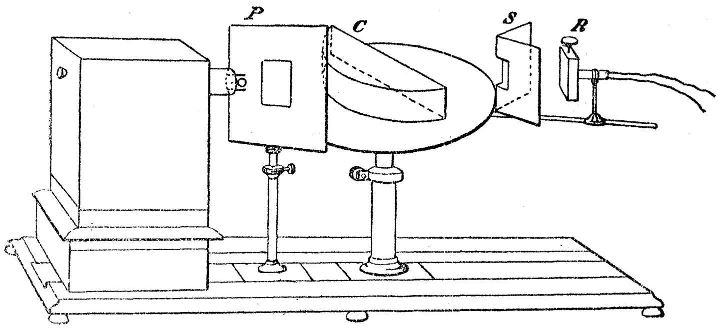

FIG. 1.—The electric refractometer: P, the plate with a diaphragm; C, the semi-cylinder of glass; S, the shield (only one shown in the diagram); R, the receiver.

than the true reading and gradually *increasing* the angle till there was a response. The receiver was then placed at a greater angle, and the angle gradually *reduced* till the receiver again responded. In this way a series of readings for a particular angle of incidence was obtained. These readings were found fairly concordant, the maximum variation from the mean being not so great as 1°. One set of readings being taken on one half of the spectrometer circle, the cylinder was rotated in the opposite direction, and readings taken on the other side.

Angle of Incidence.	Angle of Refraction.			μ.
	Reading to the right.	Reading to the left.	Mean.	
15°	31° 0′ 31 0 31 30 31 30	31° 30′ 30 30 31 30 31 30	31° 15′	2 00
20°	45° 30′ 45 30 44 30 45 30	45° 30′ 46 0 44 0 45 30	45° 15′	2·08
22°	48° 0′ 50 0 49 30 50 0	49° 30′ 50 30 48 30 50 0	49° 30′	2 ·03

Mean value of $\mu = 2·04$ .... (3).

In the next series of observations, the rays were refracted from air into glass. The electric beam was rendered parallel with the help of a glass lens (f = 4 cm.). The beam was incident on the *plane* face of the semi-cylinder. As the cylinder itself focussed the refracted beam, the objective hitherto used in conjunction with the receiver was dispensed with.

i.	r.	Mean value of r.	μ.
40°	18° 19 18	18° 20′	2·04
50°	22° 23 22° 30′	22° 30′	2·00
65°	25° 30′ 26° 27	26° 10′	2·05

Mean value of μ = 2·03 .... (4).

The different values of μ obtained are given below :—

From total reflection from a single semi-cylinder, 2·08 .... (1)
" " " two semi-cylinders .. 2·04 .... (2)
From refraction from glass into air .... 2·04 .... (3)
" " air into glass .... 2·03 .... (4)

The frequency of vibration was of the order 10^{10}.

The value of the optical index of the glass determined by the total reflection method was found to be

$$\mu_D = 1{\cdot}53.$$

"On the Influence of the Thickness of Air-space on Total Reflection of Electric Radiation." By JAGADIS CHUNDER BOSE, M.A., D.Sc., Professor of Physical Science, Presidency College, Calcutta. Communicated by LORD RAYLEIGH, F.R.S. Received November 15,—Read November 25, 1897.

In my preliminary experiments on the determination of the index of refraction of various substances for electric radiation, I used a